Ultrasound directed reduction of distal radius fractures in adults: a systematic review

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FIGURE: 1

TABLES: 3

APPENDIX: 1

ABSTRACT

OBJECTIVE:
To conduct a systematic review of the clinical literature to determine whether ultrasound can be used to improve the reduction of distal radius fractures in adults in the emergency department.

METHODOLOGY:
A study protocol was registered on PROSPERO. EMBASE, PubMed/MEDLINE, the Cochrane Central Register of Controlled Trials and ClinicalTrials.gov of U.S. National Library of Medicine were searched for studies evaluating ultrasound assisted distal radial fracture reductions in comparison to standard care. The primary outcome of interest was manipulation success rates, defined as the proportion of fracture manipulations resulting in acceptable anatomical alignment, with secondary outcome being subsequent surgical intervention rates in ultrasound and standard care group of patients.

RESULTS:
248 were screened at title and abstract and 10 studies were included for a narrative synthesis. The quality of this evidence is limited but suggests ultrasound is accurate in determining distal radius fracture reduction and may improve the quality of reduction compared to standard care. However, there is insufficient evidence to determine whether this affects the rate of subsequent surgical intervention or functional outcome.

CONCLUSION:
There is a lack of evidence that using ultrasound in the closed reduction of distal radius fractures benefits patients. Properly conducted randomized controlled trials with patient orientated outcomes are crucial to investigate this technology.

KEYWORDS: Ultrasound, Distal Radius Fracture

INTRODUCTION

Distal Radial Fracture(DRF)s are one of the most prevalent fractures treated in emergency medicine department(ED)s around the world,[1–3]. In the UK, they account for around one-sixth of all the fractures seen in the ED,[4] with approximately 71,000 patients affected each year,[5]. They are more common in the elderly,[6] frequently occurring due to falls onto an outstretched hand, and their incidence is increasing,[7].

These injuries are often associated with wrist deformity, due to fracture displacement which requires manipulation to bring the bones into anatomical alignment (fracture reduction). In the UK, initial closed Manipulation Under Anaesthesia (MUA) is commonly undertaken in the ED,,[8] by emergency physicians and this is typically carried out 'blind' without the use of real-time imaging. After manipulation, the wrist is placed in a plaster cast before getting x-rays 'in cast' to check the fracture position.

Despite ED fracture manipulation, up to as many as 41% of patients in UK subsequently require surgery by orthopaedic team to further reduce and or fixate the fracture,[9]. It has been suggested that real time imaging such as fluoroscopy or point of care ultrasound might enable more anatomical reductions and reduce this need for surgery,[10,11]. National Institute for Health and Care Excellence (NICE) and research prioritization initiatives have highlighted the need for research into the use of imaging in the reduction of DRFs in ED,[12].

Ultrasound is a harmless and potentially convenient alternative to fluoroscopy in the ED. It can be repeated, is not subject to Ionising Radiation (Medical Exposure) Regulations (IRMAR),[13], is routinely available and familiar to emergency physicians for whom point of care US is a core competency in many countries,[14]. Several small studies have described the use of ultrasound in the reduction of distal radius fractures,[10,11,15–17] in adults. Its use for identifying pediatric fractures has been well acknowledged,[18–21] and has also been used for reduction of forearm fractures in ED,[22]. However, the evidence for its use is not well established and it is not in widespread use. Furthermore, ultrasound could introduce delay to treatment, risk repeated further reduction attempts and associated complications.

There is a need for systematic review and evaluation of the available evidence to direct current best practice and future research,[23]. The purpose of this review therefore is to identify and evaluate studies to determine whether the use of ultrasound in directing a reduction of distal radius fractures in adults is beneficial in improving fracture reductions and reducing the need for subsequent surgical treatment, compared to standard manipulation without real time imaging.

METHODS

Protocol and registration

The protocol was registered in PROSPERO with the registration number CRD42019123186 before commencing the study. This systematic review was conducted with reference to the Cochrane Handbook for Systematic Reviews of Interventions,[24] and reported according to PRISMA guidelines,[25].

Information sources

The electronic databases EMBASE, PubMed/MEDLINE, CENTRAL and ClinicalTrials.gov were searched from inception until June 2019.

Search

The following search string was formed with the help of Information Specialists in The National Institute for Health Research (NIHR) Applied Research Collaboration (ARC) South West Peninsula(PenARC) Evidence Synthesis Team Search and Review Clinic in University of Exeter, Exeter, UK and translated into each database:

(ultrasound OR ultra sound OR ultra-sound OR sonograph OR sonography) AND (colles fracture OR colles fracture OR colles fractures OR colles OR distal radius fracture OR distal radius fractures OR distal radial fracture OR distal radial fractures).

After database searches, supplementary searches were conducted via Google, Google Scholar, National Institute of Health Trial registry website, International Standard Randomized Controlled Trial Number Register websites and by examining the reference lists of included studies. A post hoc MeSH term only search was also conducted, which did not provide any additional studies.

Study selection

One reviewer (HM) screened studies identified by the searches against the selection criteria below using a predesigned proforma. Studies were screened against the inclusion/exclusion criteria at title and abstract. HM identified the full texts of articles and abstract that met inclusion criteria at this stage and screened them in full. Second reviewer (AA) reviewed the studies list after de-duplication and the studies included for this review. Included studies were available at full text except one, only available as an abstract,[26]. Any disputes between the two authors were resolved through discussion.

Eligibility criteria

Study type:

Randomised Control Trials (RCT), Non-randomized Controlled Studies (NRS) and observational studies in hospital setting were included in this review. Systematic reviews, case reports and case series were not included.

Population:

All studies including adult population, aged > 18 years were included. Studies including only patients aged < 18 years were excluded.

Intervention:

Studies utilising US to direct or determine adequacy of reduction of DRF, compared with standard care were reported. Studies that used US for diagnosis of DRF alone were excluded.

Outcome:

Primary outcome measures: Manipulation success rates determined by improvement in defined radiological parameters. Secondary outcome measures: Subsequent surgical intervention rates in US and standard care group of patients.

Data collection process

HM extracted relevant data from included studies into an Excel spread sheet (2010). Data extraction was reviewed by AA.

Data items

The data extracted included: authors, year of publication, language of publication, source, country of trial, methodological quality criteria, enrolment period, sample size, patient characteristics, intervention, and outcomes (manipulation success rate and surgical intervention percentages between US and standard treatment groups).

Quality assessment of individual studies

Quality assessment was undertaken for each study by HM using Effective Public Health Practise Project's(EPHPP) Qualitative Assessment Tool for Quantitative Studies,[27] and checked by AA. This took place after studies were finalised for the narrative synthesis and helped to assess the quality of available evidence.

Outcome measures

Primary outcome measure was the difference in the percentages of successful manipulation rates between US and standard groups.

Synthesis of results

A narrative summary was conducted regarding use of US in management of distal radial fractures, given the clinical and methodological heterogeneity of the available studies.

RESULTS

Study selection

A total of 323 studies were identified via database search and 2 from Google search (Fig. 1). After de-duplication, 258 records were screened at title and abstract stage with particular attention given to the methodology section. At full text stage, 25 studies were screened and 10 included for the narrative synthesis.

Nine studies,[10,11,15–17,28–31] were identified as observational studies and one study was identified as randomised controlled trial,[26]. This RCT was published as an abstract,[26], and the author, upon contact, confirmed that there was no full text published. However, we chose to include this abstract due to its informative content.
There were six other trials,[32–38] identified on Clinicaltrials.gov, Netherlands Trial Register(NTR) and WHO International Clinical Trials Registry(ICTRP) during the screening stage but none were published or had any results posted. One trial was incomplete due to recruitment issues,[36], two trials from Canada,[32,34],one study from Iran,[38] did not publish any results and the concerned personnel did not respond to the emails. One RCT was identified on Netherlands Trial Register,[37] but there was no response from the team and the trial registry had no update regarding the study. The only active RCT was a feasibility trial from UK which started recruiting in October 2019,[35].
As shown in Table 1, 10 studies were included for the Narrative synthesis.

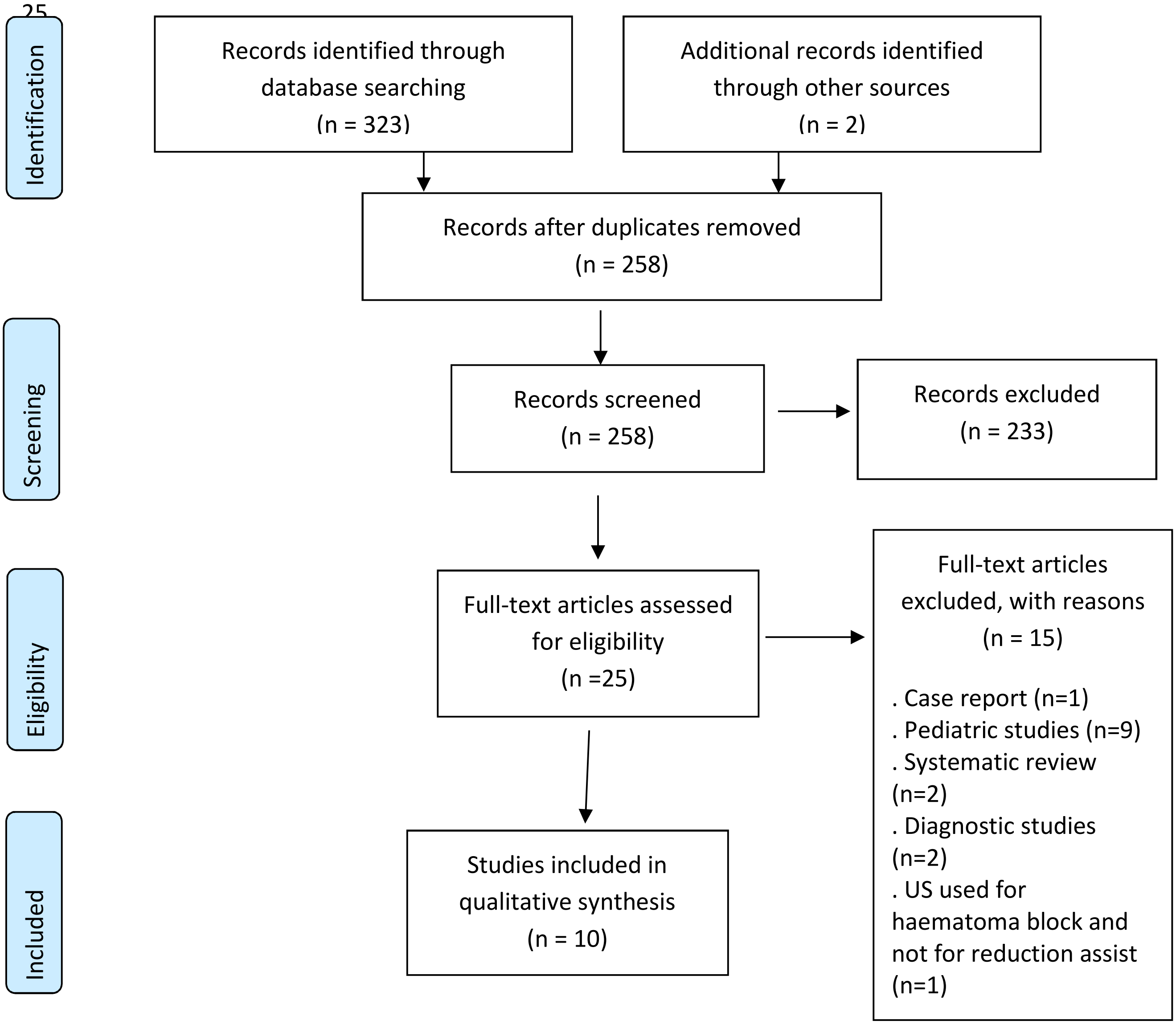

Fig.1 Flow diagram showing study selection

Study characteristics

Four of the included studies were Cohort studies,[11,15,16,29], among which two were multicentre,[15,29],one study was a Before-and-After study,[39], two studies were cross-sectional,[28,31], two were case-control,[17,30] and one was a RCT,[26]. All manuscripts were published in English from year 2002 till 2018 and originated in Taiwan,[16], Singapore,[10], USA,[15,30], Canada,[26,29], Japan,[11], Iran,[17,28] and Turkey,[40]. All studies included adult population except for two studies,[15,16] which also included children but did not give a separate data for them, with the age range of 3-95 years. The total number of patients in the included studies was 956, of which 638 received US assisted reduction of a DRF. Primary outcome of manipulation success rate was clearly described in 6 studies,[11,15,17,26,28,31] and secondary outcome involving surgical intervention after initial fracture manipulation was given in only four,[10,15,17,26]. Study characteristics are summarized in Table 1.

Table 1. Study characteristics of individual studies

Authors	Study type	Publication year	Language	Source	Country	Sample size	Interventional arm	Control arm	Age
1. Chern T-C et al	Prospective Cohort study	2002	English	Online Journal	Taiwan	27	27	N/A	Adults and children aged 8 - 86 years
2. Ang S-H et al	Before-and-After Study	2009	English	Online Journal	Singapore	164	62	102	Adults > 21 years
3. Chinnock B et al	Multicentre Cohort Study	2009	English	Online Journal	USA	100	46	44	Adults and Children aged 3-87 years
4. Brahm J, Turner J	Randomized Controlled trial	2011	English	Online Journal	Canada	47	27	20	Adults > 18 years
5. Kodama N et al	Cohort Study	2013	English	Online Journal	Japan	100	43	57	Adults 23-93 years
6. Esmailian M et al	Prospective Cross-sectional	2013	English	Online Journal	Iran	154	154	N/A	Adults 22-73 years
7. Sabzghabaei A et al	Case-Control study	2016	English	Online Journal	Iran	130	65	65	Adults > 18 years
8. Socransky S et al	Multicentre prospective cohort	2016	English	Online Journal	Canada	131	131	N/A	Adults aged 18-95 years
9. Lau BC et al.	Case-Control study	2017	English	Online Journal	USA	43	23	20	Adults >18 years
10. Bozkurt O et al	Prospective cross-sectional	2018	English	Online Journal	Turkey	60	60	N/A	Adults 18-83 years

Quality assessment of studies

Quality assessment was undertaken by using Effective Public Health Practise Project's(EPHPP) Qualitative Assessment Tool for Quantitative Studies,[27] as shown in Table 2. This tool used eight components to assess the quality of a study: Selection bias, Study design, Confounders, Blinding, Data collection methods, Withdrawals and drop-outs, Intervention integrity and Analysis appropriate to question. All components except for the last two: Intervention integrity and Analysis appropriate to question, needed rating. Each component could be rated as Strong, Moderate or Weak based on a questionnaire tool done for each individual study. The questionnaire tool was filled with the help of EPHPP dictionary. After all components were rated in the questionnaire tool, final rating of the individual paper was determined by the following pre-set criteria: Strong if no weak component, moderated if one weak component or Weak if two or more weak components. The majority of the studies,[11,16,17,26,28–31] had a weak global rating mainly due to not reporting controlling for confounders, data collection methods and follow up data for participants. The only RCT,[26], although having a strong study design, which also addressed for the confounders, had a weak global rating, due to limited information due to being in abstract form, regarding data collection and follow-up of patients.

Table 2. Quality assessment of individual studies.

Authors	Selection bias	Study design	Confounders	Blinding	Data collection method	Withdrawals and dropouts	Global rating
1. Chern T-C et al	Moderate	Moderate	Weak	Moderate	Moderate	Weak	Weak
2. Ang S-H et al	Moderate	Moderate	Strong	Weak	Strong	Strong	Moderate
3. Chinnock B et al	Moderate	Moderate	Weak	Moderate	Moderate	Strong	Moderate
4. Brahm J, Turner J	Moderate	Strong	Strong	Moderate	Weak	Weak	Weak
5. Kodama N et al	Moderate	Moderate	Weak	Moderate	Weak	Weak	Weak
6. Esmailian M et al	Moderate	Moderate	Weak	Moderate	Weak	Strong	Weak
7. Sabzghabaei A et al	Moderate	Strong	Strong	Weak	Moderate	Weak	Weak
8. Socransky S et al	Moderate	Moderate	Weak	Weak	Moderate	Strong	Weak
9. Lau BC et al.	Moderate	Moderate	Weak	Moderate	Moderate	Weak	Weak
10. Bozkurt O et al	Moderate	Moderate	Weak	Strong	Moderate	Weak	Weak

Results of individual studies and synthesis of results

Results of individual studies are summarized in Table 3. Below is the synthesis of findings from included studies.

Manipulation success rate:
Manipulation success rate was significantly($p<0.05$) increased in one study,[17] compared to the standard group. Three studies showed statistically non-significant($p>0.05$) increased manipulation success rate in the US assisted DRF reductions,[11,15,26]. Bozkurt et al,[40] showed a 97.5% success rate in US group but no number was available for the control arm. Esmailian et al,[41] showed a slightly lower rate of 94.2 % compared to 94.8% in the control group. Socransky et al,[29] showed that on repeat reduction attempt, US use led to 93.9% adequate reductions in comparison to 55.1% using clinical assessment.

Surgical fixation rate:
Two studies,[10,17] showed a significant($p<0.05$) reduction in surgical rate seen in the US group. The only RCT in this review,[26] however, showed no difference in the rate of surgery between the two groups. Interestingly, this study also showed that a significantly greater number of attendings (consultants) performed reductions in the standard group,65%($p=0.02$) and details of randomisation and any concealment measures were not available despite a direct correspondence request to the authors. Chinnock et al had 6.5% patients undergo surgical fixation in the US group but no numbers were present for the control group.

Accuracy of detecting a successful fracture reduction:
Four studies,[15,28,30,31] determined US to have a higher sensitivity, three,[28,30,31] having a higher sensitivity and specificity, and three,[15,28,31] having a higher positive predictive value in detecting successful fracture reduction. Socransky et al,[29]reported a greater certainty regarding adequacy of reduction using US.

Improvement in radiological parameters:
All studies used radial shortening distance, radial inclination angle and volar tilting angle as the radiological parameters to determine adequacy of reduction. Two studies,[10,17] showed US to significantly($p<0.05$) improve the volar tilt. Chern et al reported a significant($p<0.05$) improvement in all radiological parameters, whereas Kodama et al,[11] showed no difference between two groups.

Table 3. Results of individual studies.

Authors	Rate of fracture reduction success				Accuracy of detecting successful fracture reduction				Surgical fixation			Improvement in radiological parameters
	US	CG		P-value	SN	SP	PPV	NPV	US	CG	P-value	
1. **Chern T-C et al**	N/A	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	P< 0.05
2. **Ang S-H et al**	N/A	N/A		N/A	N/A	N/A	N/A	N/A	4.9%	16.7%	P=0.019	Volar tilt t-test value= 0.048
3. **Chinnock B et al**	83%	80%		p>0.05	94%	56%	89%	71%	6.5%	N/A	N/A	N/A
4. **Brahm J, Turner J**	92.6%	90%		P=1.00	N/A	N/A	N/A	N/A	29.6%	25%	P=1.00	N/A
5. **Kodama N et al**	95%	94% in FG	68% in BPG	p>0.05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	p>0.05
6. Esmailian M et al	94.2%	94.8%		N/A	99.3%	100%	100%	88.9%	N/A	N/A	N/A	N/A
7. **Sabzghabaei A et al**	92.3%	78.5%		P=0.025	N/A	N/A	N/A	N/A	10.8%	27.7%	**P=0.014**	Volar tilt p< 0.001
8. **Socransky S et al**	Greater certainty regarding adequacy of reduction, p=0.008. 93.9% adequate reduction in repeat reduction US group compared to 55.1% using clinical assessment											
9. **Lau BC et al.**	N/A	N/A		N/A	76%-93%	93%-94%	N/A	N/A	N/A	N/A	N/A	N/A
10. Bozkurt O et al	97.5%	N/A		N/A	97.5%	95%	97.5%	95%	N/A	N/A	N/A	N/A

US=Ultrasound, CG=Control Group, SN=Sensitivity, SP=Specificity, PPV=Positive Predictive Value, NPV=Negative Predictive Value, FG=Fluoroscopy Group, BPG=Blind Procedure Group.

DISCUSSION

We conducted a systematic review to identify, assess and summarize the literature reporting the use of ultrasound to assist in the closed reduction of distal radius fractures in adults. This review identified 10 studies from seven countries, with methodological heterogeneity and a total sample size of 956 patients. There is a suggestion that US may be a useful adjunct for the closed manipulation of DRFs. Its use is associated with a higher fracture reduction success rate,[11,15,17,26,31] higher sensitivity in detecting an adequate reduction,[15,28,30,31] and hints at a possible reduction in subsequent surgical fixation rate,[17,39] when compared to control groups. However, the overall quality of the studies and their evidence is weak. The sole RCT addressing the issue is of limited size, only reported in abstract and so significant methodological limitations cannot be excluded.

However, ultrasound does provide real time imaging and aids anatomic alignment during fracture reduction. It is plausible that this would enable better reduction as compared to a blind technique or clinical assessment. At least in the UK, where alternative real time imaging in ED is rarely available, US would seem a practical and pragmatic imaging option. US is cost effective in comparison to alternative imaging modalities used in a range of Emergency Department presentations,[42]. Accuracy of US in detecting fractures is well evidenced,[43,44] and our review also supports its high sensitivity and specificity for detecting an adequate fracture reduction. It provides a greater certainty of reduction,[29] allows repeated attempts of manipulation before plaster cast immobilization and confirmatory x-rays. It has given comparable results to other real time imaging techniques like Fluoroscopy,[11].

DRFs undergo surgical fixation if the initial fracture manipulation or position at follow up is felt unsatisfactory usually by an orthopaedic surgeon. Four studies reported this outcome and two showed a significant reduction in the surgical fixation rates in US assisted reductions,[17,39]. The only RCT in this review however reported no difference in rate of surgery in the US group compared to the control arm. This discrepancy could be due to the methodology of these studies. However, it has important implications for a resource limited setting like ED. None of the key studies reported on functional outcomes. This and other patient oriented outcomes,[45] should be a key component of future studies.

This is the only systematic review to date to have explored literature regarding US assisted reduction of DRF in adults. We have used a broad search strategy, to include all published and non-published literature. We included studies involving US in any aspect of closed DRF reduction, did not limit our search to language and a thorough quality appraisal was undertaken. All the studies appraised in this review presented some flaws and limitations which should be addressed in future studies. The majority of studies were of weak quality, mainly due to weakness of study design, follow up data and data collection methods and the presence of confounders. There was no power calculation in the majority of studies, healthy controls used in some studies and no comparison or control group in one,[16]. The review as a whole faced clinical and methodological heterogeneity. There was a small number of studies and one was an abstract. All efforts were made to inquire more about data and unpublished material, but no author corresponded to the emails except one,[26]. Another limitation of this review is only one reviewer for the primary screening of studies. All steps were taken to build a credible search strategy, but this could also be a limiting factor. Grey literature was assessed for the completion of this review, but we cannot rule out the possibility that other unpublished evidence was missed.

CONCLUSION

Ultrasound to assist in the reduction of distal radius fractures is a plausible and potentially helpful cost-effective method to guide reductions in the ED. It is accurate in detecting fracture reductions and if it's use, as this review suggests, improves the quality of these reductions, it could conceivably influence the subsequent need for surgery. However, only observational studies and 1 RCT of limited quality has been conducted to date and none have included patient orientated outcomes. There is therefore currently insufficient evidence to justify the routine use of US to assist in the reduction of these common fractures. Adequately powered, high quality randomised controlled trials with appropriate and meaningful patient orientated outcomes are crucial to determine if there are any benefits of ultrasound use to assist in the reduction of distal radius fractures in the ED.

COMPETING INTEREST

None declared

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REFERENCES

1 Tsai C-H, Muo C-H, Fong Y-C, *et al.* A population-based study on trend in incidence of distal radial fractures in adults in Taiwan in 2000–2007. *Osteoporos Int* 2011;**22**:2809–15. doi:10.1007/s00198-010-1489-6

2 Jerrhag D, Englund M, Karlsson MK, *et al.* Epidemiology and time trends of distal forearm fractures in adults - a study of 11.2 million person-years in Sweden. *BMC Musculoskelet Disord* 2017;**18**:240. doi:10.1186/s12891-017-1596-z

3 Immerman I, Livermore MS, Szabo RM. Use of emergency department services for hand, wrist, and forearm fractures in the United States in 2008. *J Surg Orthop Adv* 2014;**23**:98–104.

4 Goldie BS. DISTAL RADIUS FRACTURES IN ADULTS. *Orthop Proc* 2002;**84-B**:358. doi:10.1302/0301-620X.84BSUPP_III.0840358

5 O'Neill TW, Cooper C, Finn JD, *et al.* Incidence of distal forearm fracture in British men and women. *Osteoporos Int* 2001;**12**:555–8.

6 Thompson PW, Taylor J, Dawson A. The annual incidence and seasonal variation of fractures of the distal radius in men and women over 25 years in Dorset, UK. *Injury* 2004;**35**:462–6. doi:10.1016/S0020-1383(03)00117-7

7 Nellans KW, Kowalski E, Chung KC. The epidemiology of distal radius fractures. *Hand Clin* 2012;**28**:113–25. doi:10.1016/j.hcl.2012.02.001

8 Bin Musarraf SAA. Clinical Literature Review on Ultrasound Guided Manipulation of Distal Radius Fracture. *Int Ann Med* 2018;**2**. doi:10.24087/IAM.2018.2.12.701

9 Malik H, Appelboam A, Taylor G. Colles' type distal radial fractures undergoing manipulation in the ED: a multicentre observational cohort study. *Emerg Med J* 2020;:emermed-2020-209478. doi:10.1136/emermed-2020-209478

10 Ang S-H, Lee S-W, Lam K-Y. Ultrasound-guided reduction of distal radius fractures. *Am J Emerg Med* 2010;**28**:1002–8. doi:10.1016/j.ajem.2009.05.022

11 Kodama N, Takemura Y, Ueba H, *et al.* Ultrasound-Assisted Closed Reduction of Distal Radius Fractures. *J Hand Surg Am* Published Online First: 2014. doi:10.1016/j.jhsa.2014.02.031

12 Fractures (non-complex): assessment and management | NICE. https://www.nice.org.uk/researchrecommendation/image-guidance-in-the-reduction-of-displaced-distal-radius-fractures-for-patients-with-displaced-fractures-of-the-distal-radius-is-manipulation-with-real-time-image-guidance-more-clinically-and-cost-effective-than-manipulation-without-real-time-image-guid (accessed 13 Apr 2019).

13 Ionising radiation - Health Research Authority. https://www.hra.nhs.uk/planning-and-improving-research/policies-standards-legislation/ionising-radiation/ (accessed 19 Jun 2020).

14 Dick EA, Varma D, Kashef E, *et al.* Use of advanced imaging techniques during visits to emergency departments-implications, costs, patient benefits/risks. Br. J. Radiol. 2016;**89**. doi:10.1259/bjr.20150819

15 Chinnock B, Khaletskiy A, Kuo K, *et al.* Ultrasound-guided reduction of distal radius fractures. *J Emerg Med* 2011;**40**:308–12. doi:10.1016/j.jemermed.2009.09.018

16 Chern T-C, Jou I-M, Lai K-A, *et al.* Sonography for monitoring closed reduction of displaced extra-articular distal radial fractures. *J Bone Joint Surg Am* 2002;**84-A**:194–203.http://www.ncbi.nlm.nih.gov/pubmed/11861724 (accessed 11 May 2019).

17 Sabzghabaei A, Shojaee M, Arhami Dolatabadi A, *et al.* Ultrasound-Guided Reduction of Distal Radius Fractures. *Emerg (Tehran, Iran)* 2016;**4**:132–5.http://www.ncbi.nlm.nih.gov/pubmed/27299141 (accessed 1 Apr 2019).

18 Wang CC, Linden KL, Otero HJ. Sonographic Evaluation of Fractures in Children. J. Diagnostic Med. Sonogr. 2017;**33**:200–7. doi:10.1177/8756479316688897

19 Williamson D, Watura R, Cobby M. Ultrasound imaging of forearm fractures in children: A viable alternative? *J Accid Emerg Med* 2000;**17**:22–4. doi:10.1136/emj.17.1.22

20 Barata I, Spencer R, Suppiah A, *et al.* Emergency ultrasound in the detection of pediatric long-bone fractures. *Pediatr Emerg Care* 2012;**28**:1154–7. doi:10.1097/PEC.0b013e3182716fb7

21 Hubner U, Schlicht W, Outzen S, *et al.* Ultrasound in the diagnosis of fractures in children. *J Bone Jt Surg - Ser B* 2000;**82**:1170–3. doi:10.1302/0301-620X.82B8.10087

22 Wellsh BM, Kuzma JM. Ultrasound-guided pediatric forearm fracture reductions in a resource-limited ED. *Am J Emerg Med* 2016;**34**:40–4. doi:10.1016/j.ajem.2015.09.013

23 Charrois TL. Systematic reviews: what do you need to know to get started? *Can J Hosp Pharm* 2015;**68**:144–8.http://www.ncbi.nlm.nih.gov/pubmed/25964686 (accessed 13 May 2019).

24 *Cochrane Handbook for Systematic Reviews of Interventions*. 2019. doi:10.1002/9781119536604

25 Moher D, Liberati A, Tetzlaff J, *et al.* Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med* 2009;**6**:e1000097. doi:10.1371/journal.pmed.1000097

26 Brahm J, Turner J. 158 A Randomized Controlled Trial of Emergency Department Ultrasound-Guided Reduction of Distal Radius Fractures. *Ann Emerg Med* 2011;**58**:S230–1. doi:10.1016/j.annemergmed.2011.06.186

27 National Collaborating Centre for Methods and Tools. Quality assessment tool for quantitative studies. Eff. Public Heal. Pract. Proj. McMaster Univ. Toronto. 2010.

28 Esmailian M, Haj Zargarbashi E, Masoumi B, *et al.* Accuracy of Ultrasonography in Confirmation of Adequate Reduction of Distal Radius Fractures. *Emerg (Tehran, Iran)* 2013;**1**:7–10.

29 Socransky S, Skinner A, Bromley M, *et al.* Ultrasound-Assisted Distal Radius Fracture Reduction. *Cureus* 2016;**8**:e674. doi:10.7759/cureus.674

30 Lau BC, Robertson A, Motamedi D, *et al.* The Validity and Reliability of a Pocket-Sized Ultrasound to Diagnose Distal Radius Fracture and Assess Quality of Closed Reduction. *J Hand Surg Am* 2017;**42**:420-427. doi:10.1016/j.jhsa.2017.03.012

31 Bozkurt O, Ersel M, Karbek Akarca F, *et al.* The diagnostic accuracy of ultrasonography in determining the reduction success of distal radius fractures. *Turkish J Emerg Med* 2018;**18**:111–8. doi:10.1016/j.tjem.2018.04.001

32 NCT02962206. The Effect of Point-of-care Ultrasound Guidance for Distal Radius Fracture Reduction. *Https://clinicaltrials.gov/show/nct02962206* Published Online First: 2016.https://www.cochranelibrary.com/central/doi/10.1002/central/CN-01559956/full

33 NCT02353065. Sonographic Assessment of Reduction in Colles' Fracture. *Https://clinicaltrials.gov/show/nct02353065* Published Online First: 2015.https://www.cochranelibrary.com/central/doi/10.1002/central/CN-01551886/full

34 Ultrasound Assisted Distal Radius Fracture Reduction - Full Text View - ClinicalTrials.gov. https://clinicaltrials.gov/ct2/show/NCT01561573?term=ultrasound+OR+ultra+sound+OR+ultra-sound+OR+sonograph+OR+sonography&cond=colles%2C+fracture+OR+colles+fracture+OR+colles+fractures+OR+colles+OR+distal+radius+fracture+OR+distal+radius+fractures+OR+dista (accessed 12 May 2019).

35 Ultrasound Directed Reduction of Colles Type Distal Radial Fractures in ED (UDiReCT) - Full Text View - ClinicalTrials.gov. https://clinicaltrials.gov/ct2/show/NCT03868696?term=ultrasound&cond=Colles%27+Fracture&rank=2 (accessed 14 Jun 2019).

36 Sonographic Assessment of Reduction in Colles' Fracture - Full Text View - ClinicalTrials.gov. https://clinicaltrials.gov/ct2/show/NCT02353065?term=ultrasound&cond=Colles%27+Fracture&rank=1 (accessed 9 May 2019).

37 NTR5837. Clinical value of ultrasound in reduction of displaced wrist fractures. *Http://www.who.int/trialsearch/trial2.aspx? Trialid=ntr5837* Published Online First: 2016.https://www.cochranelibrary.com/central/doi/10.1002/central/CN-01881978/full

38 Evaluating Validity of Ultrasonography in Determining Distal Radius Fracture Reduction - Full Text View - ClinicalTrials.gov. https://clinicaltrials.gov/ct2/show/NCT01823692?term=ultrasound+OR+ultra+sound+OR+ultra-sound+OR+sonograph+OR+sonography&cond=colles%2C+fracture+OR+colles+fracture+OR+colles+fractures+OR+colles+OR+distal+radius+fracture+OR+distal+radius+fractures+OR+dista (accessed 12 May 2019).

39 Ang S-H, Lee S-W, Lam K-Y. Ultrasound-guided reduction of distal radius fractures. *Am J Emerg Med* 2010;**28**:1002–8. doi:10.1016/j.ajem.2009.05.022

40 J. S, J. H, L. W, *et al.* The Pronator Quadratus Muscle After Volar Plating: Ultrasound Evaluation of Anatomical Changes Correlated to Patient-Reported Clinical Outcome. *Hand (N Y)* 2019;:1558944719840737. doi:http://dx.doi.org/10.1177/1558944719840737

41 Grewal R, Perey B, Wilmink M, *et al.* A randomized prospective study on the treatment of intra-articular distal radius fractures: open reduction and internal fixation with dorsal plating versus mini open reduction, percutaneous fixation, and external fixation. *J Hand Surg Am* 2005;**30**:764–72. doi:10.1016/j.jhsa.2005.04.019

42 Bierig SM, Jones A. Accuracy and Cost Comparison of Ultrasound Versus Alternative Imaging Modalities, Including CT, MR, PET, and Angiography. *J Diagnostic Med Sonogr* 2009;**25**:138–44. doi:10.1177/8756479309336240

43 Douma-den Hamer D, Blanker MH, Edens MA, *et al.* Ultrasound for Distal Forearm Fracture: A Systematic Review and Diagnostic Meta-Analysis. *PLoS One* 2016;**11**:e0155659. doi:10.1371/journal.pone.0155659

44 Kozaci N, Ay MO, Akcimen M, *et al.* Evaluation of the effectiveness of bedside point-of-care ultrasound in the diagnosis and management of distal radius fractures. *Am J Emerg Med* 2015;**33**:67–71. doi:10.1016/j.ajem.2014.10.022

45 van Leerdam RH, Huizing F, Termaat F, *et al.* Patient-reported outcomes after a distal radius fracture in adults: a 3–4 years follow-up. *Acta Orthop* 2019;**90**:129–34. doi:10.1080/17453674.2019.1568098

APPENDIX:

Database(s): **Embase** 1974 to 2019 October 29
Search Strategy:

#	Searches	Results
1	ultrasound.ti,ab,kw.	377495
2	ultra sound.ti,ab,kw.	1352
3	ultra-sound.ti,ab,kw.	1352
4	sonography.ti,ab,kw.	46054
5	sonograph.ti,ab,kw.	112
6	1 or 2 or 3 or 4 or 5	410079
7	colles,fracture.ti,ab,kw.	682
8	Colles fracture/	1063
9	colles fractures.ti,ab,kw.	392
10	colles.ti,ab,kw.	1105
11	distal radius fracture/	1090
12	distal radius fractures.ti,ab,kw.	2792
13	distal radial fracture.ti,ab,kw.	392
14	distal radial fractures.ti,ab,kw.	709
15	7 or 8 or 9 or 10 or 11 or 12 or 13 or 14	5200
16	6 and 15	121